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Nagahama

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(54) **ELECTRONIC TIMEPIECE WITH INTERNAL ANTENNA**

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(73) Assignee: **Seiko Epson Corporation** (JP)

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(22) Filed: **Sep. 3, 2013**

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H01Q 1/44 (2006.01)
G04R 60/10 (2013.01)
G04R 20/04 (2013.01)

(52) **U.S. Cl.**

CPC ***H01Q 1/44*** (2013.01); ***G04R 60/10*** (2013.01); *G04R 20/04* (2013.01)

(58) **Field of Classification Search**

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USPC 343/718, 720; 368/47, 278
See application file for complete search history.

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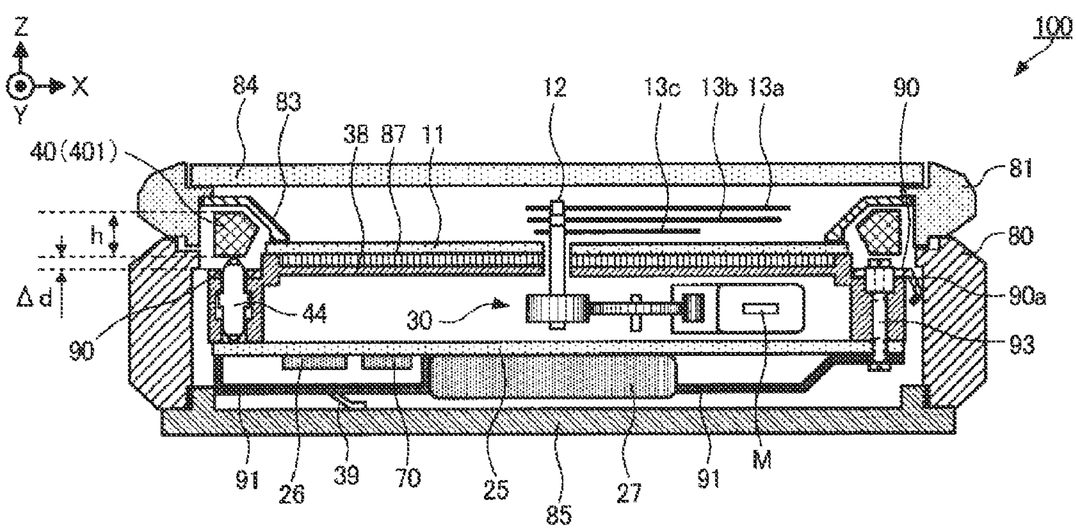
(57) **ABSTRACT**

An electronic timepiece has a case; a time display unit housed in the case; an annular dielectric that is housed in the case and has a conductive driven element to which a specific potential is supplied; and a conductive ground plane with an annular shape that is housed in the case and supplied with ground potential. The dielectric body and the ground plane are disposed coaxially to the same center axis with the gap therebetween in the axial (z-axis) direction less than or equal to the thickness of the dielectric in the axial direction.

8 Claims, 13 Drawing Sheets



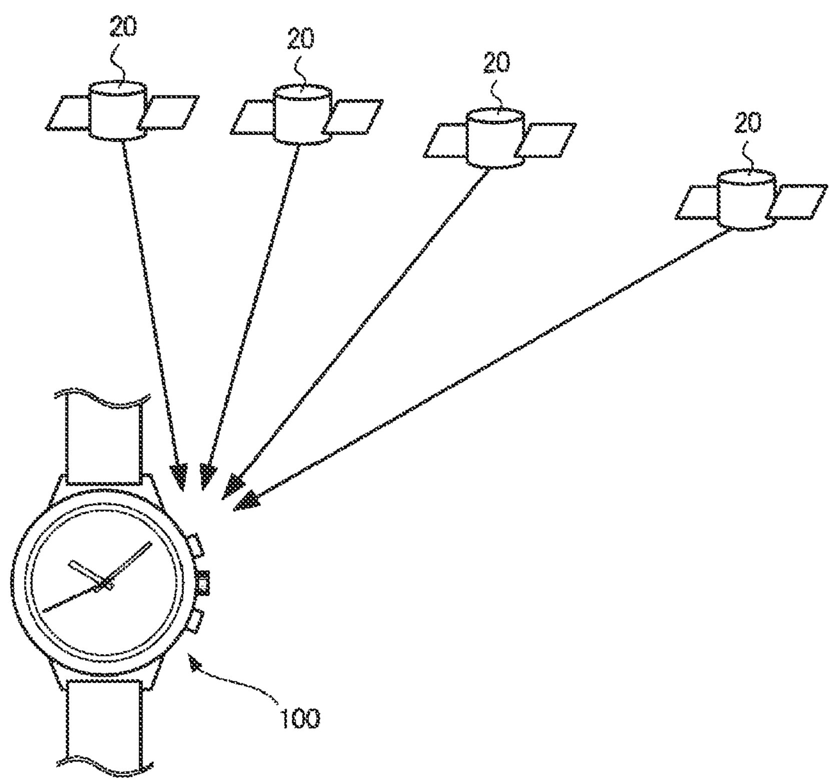
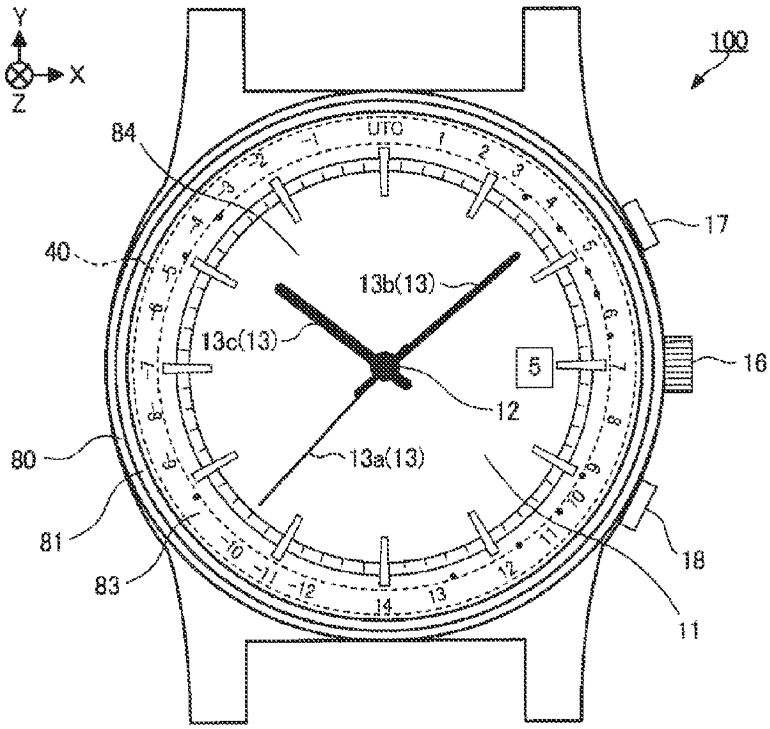
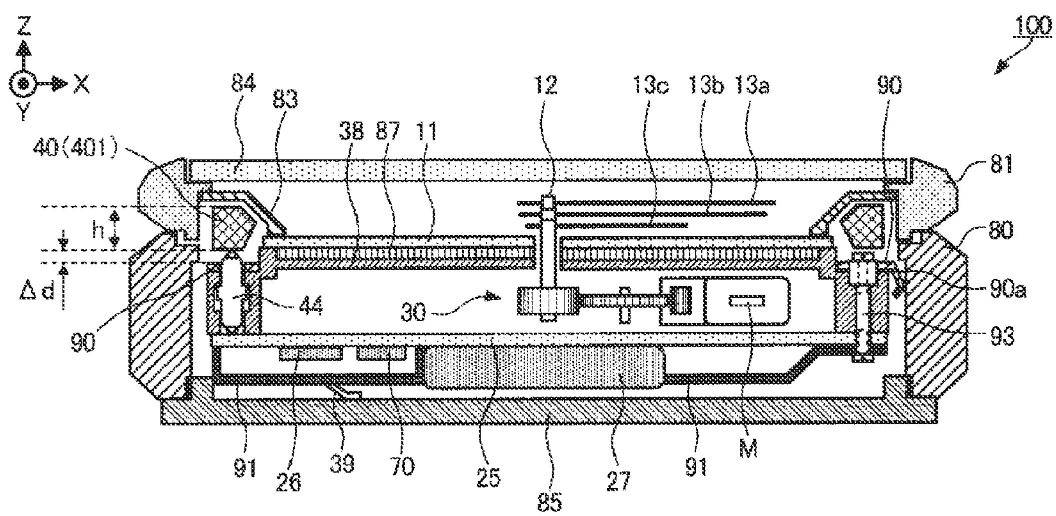


FIG. 1



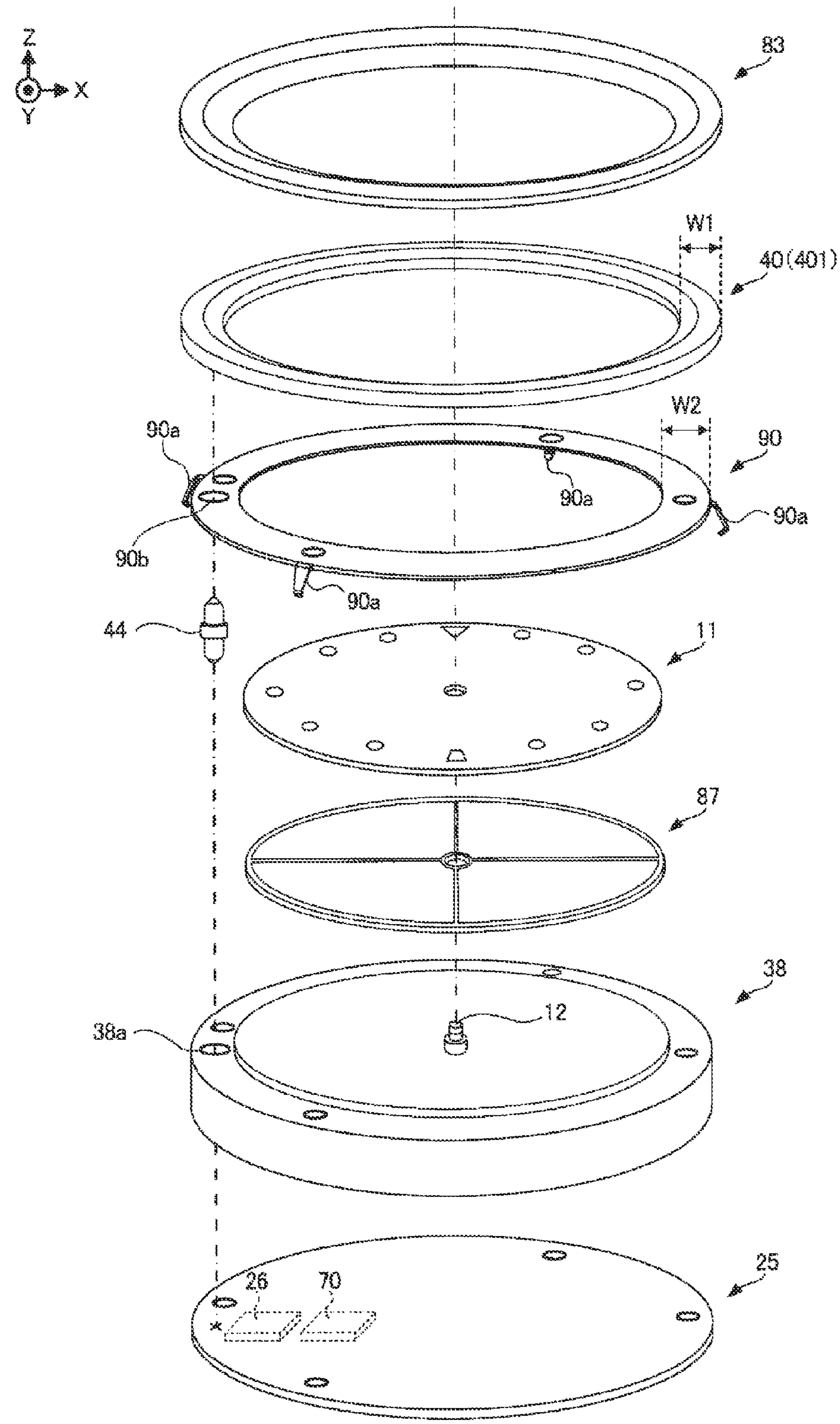
Y
X
Z
100
84
UTC
17
40
13b(13)
13c(13)
5
16
12
80
13a(13)
81
18
83
11

FIG. 2



Z
X
Y
100
84
83
12
13c
13b
13a
90
40(401)
38
87
11
81
h
80
Δd
44
30
90a
90
93
91
26
39
70
25
85
27
91
M

FIG. 3


Z
X
Y
83
W1
40(401)
100
W2
90a
90
90a
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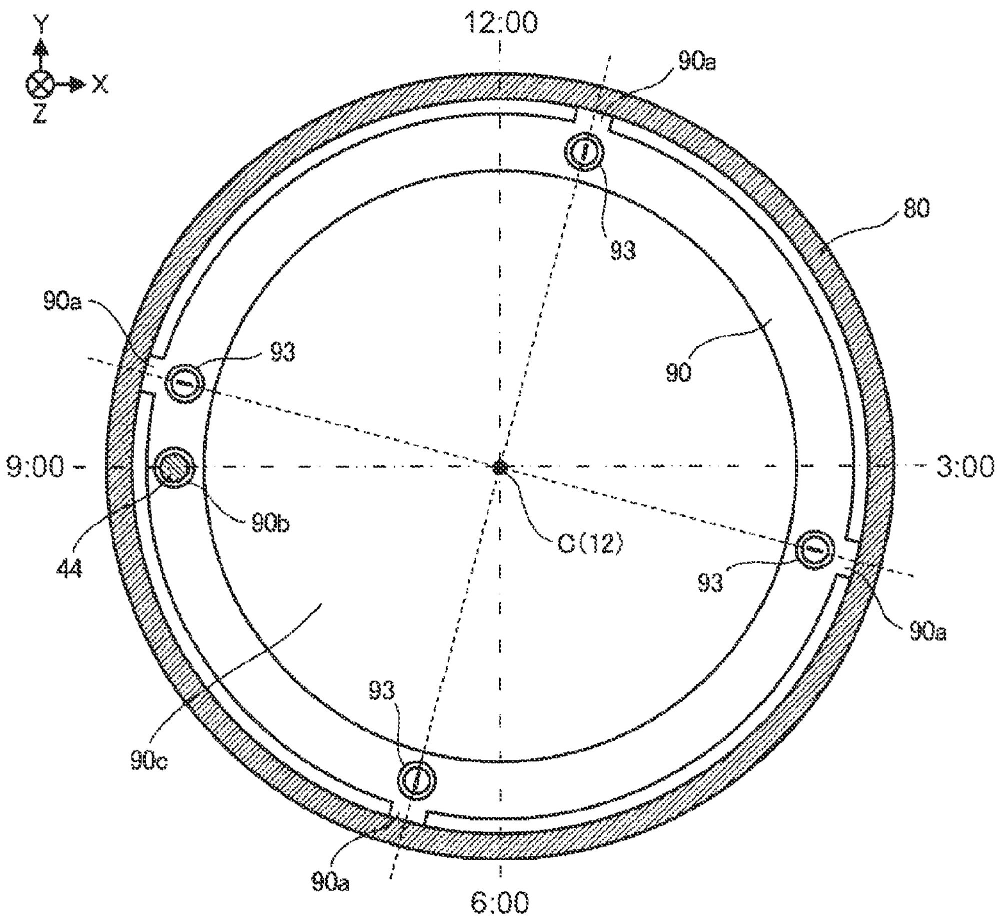
90b
90a
44
11
87
38
12
38a
25
26
70

FIG. 4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90c
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6:00

FIG. 5

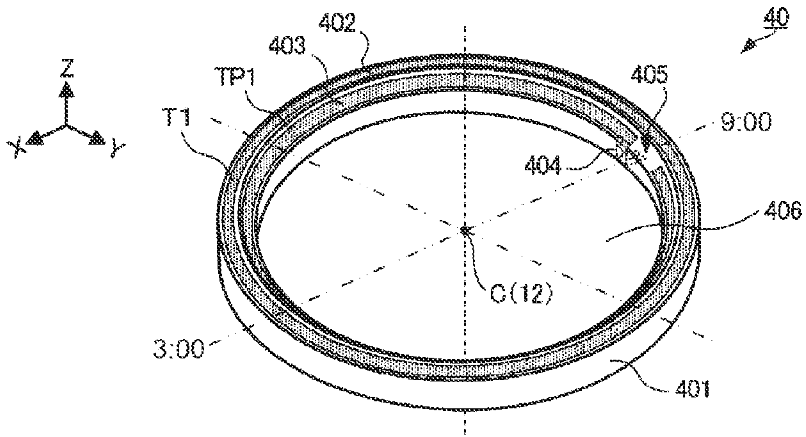


FIG. 6A

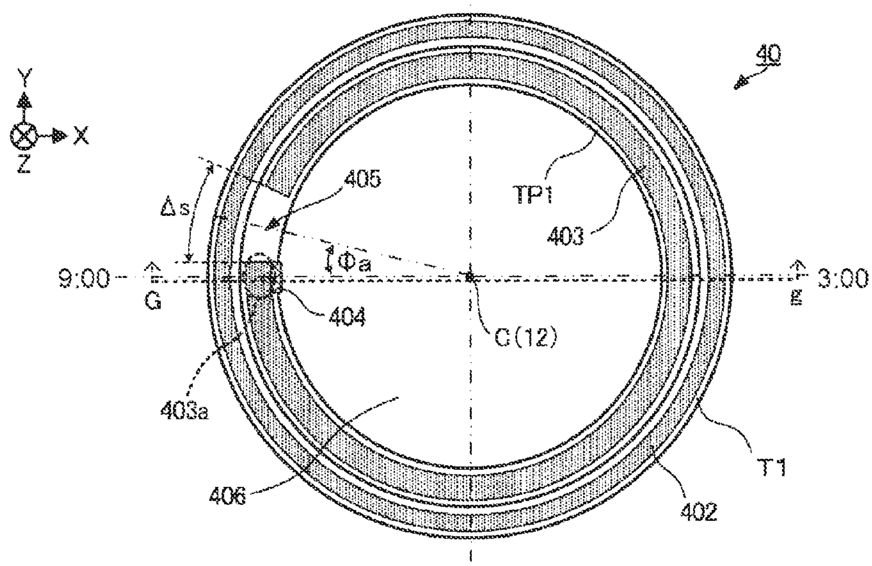


FIG. 6B

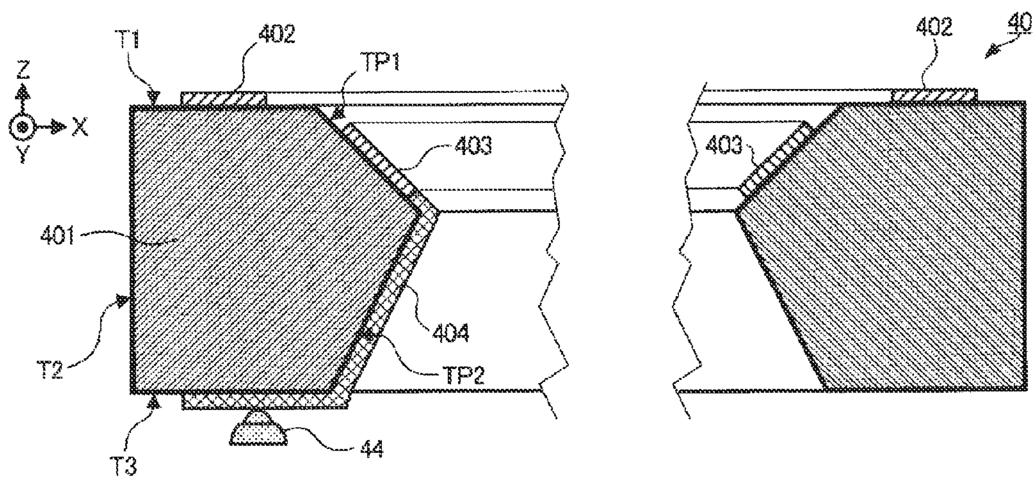


FIG. 6C

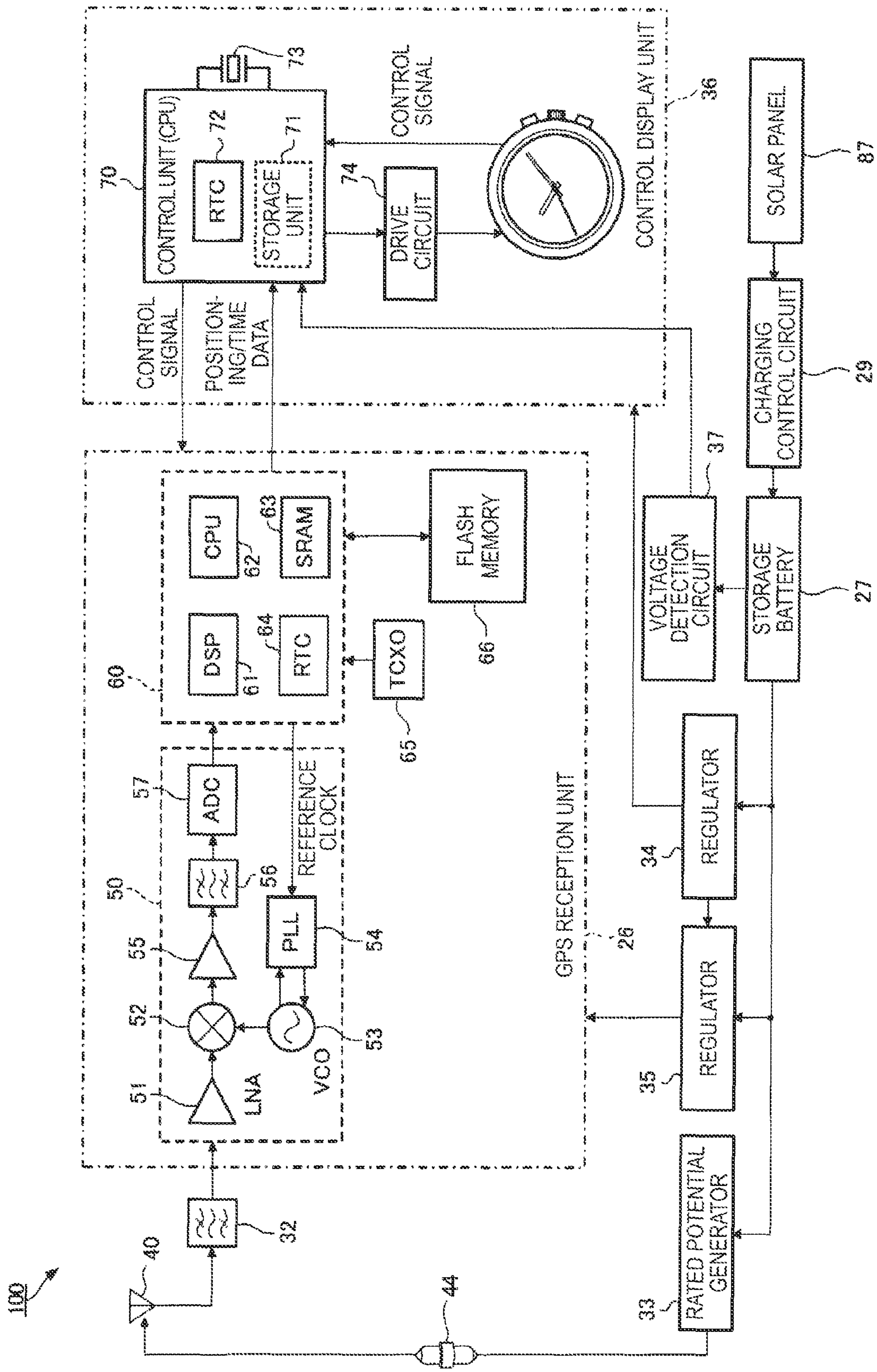
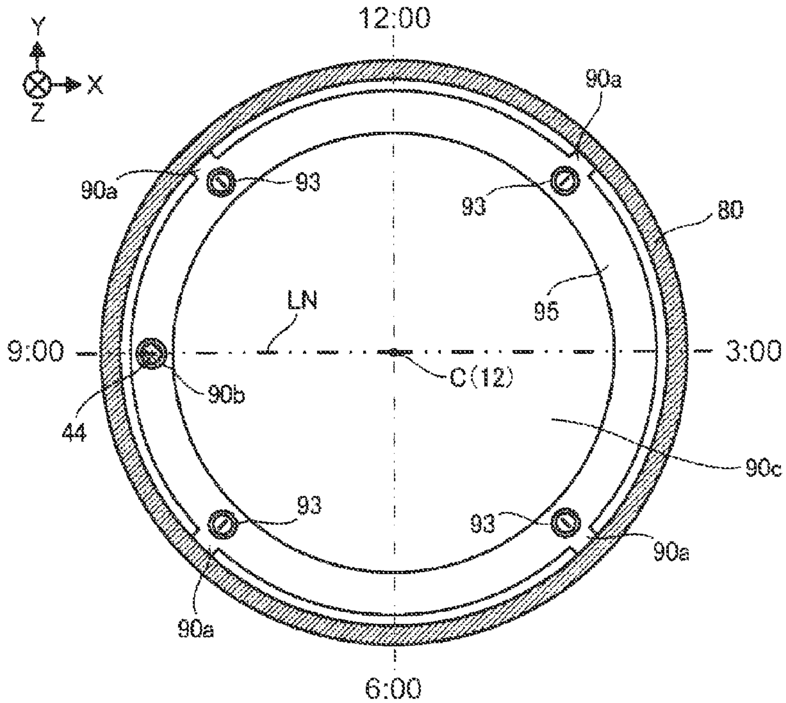

100
40
32
44
33
RATED POTENTIAL GENERATOR
LNA
51
52
VCO
53
55
50
56
PLL
54
ADC
57
REFERENCE CLOCK
60
DSP
61
64
RTC
CPU
62
63
SRAM
TCXO
65
FLASH MEMORY
66
GPS RECEPTION UNIT
26
35
REGULATOR
34
REGULATOR
VOLTAGE DETECTION CIRCUIT
37
STORAGE BATTERY
27
CHARGING CONTROL CIRCUIT
29
SOLAR PANEL
87
CONTROL SIGNAL
POSITION-ING/TIME DATA
70
CONTROL UNIT (CPU)
RTC
72
STORAGE UNIT
71
73
74
DRIVE CIRCUIT
CONTROL SIGNAL
CONTROL DISPLAY UNIT
36

FIG. 7



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X
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90a
93
93
80
95
LN
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3:00
C(12)
90b
44
90c
93
93
90a
90a
6:00

FIG. 8

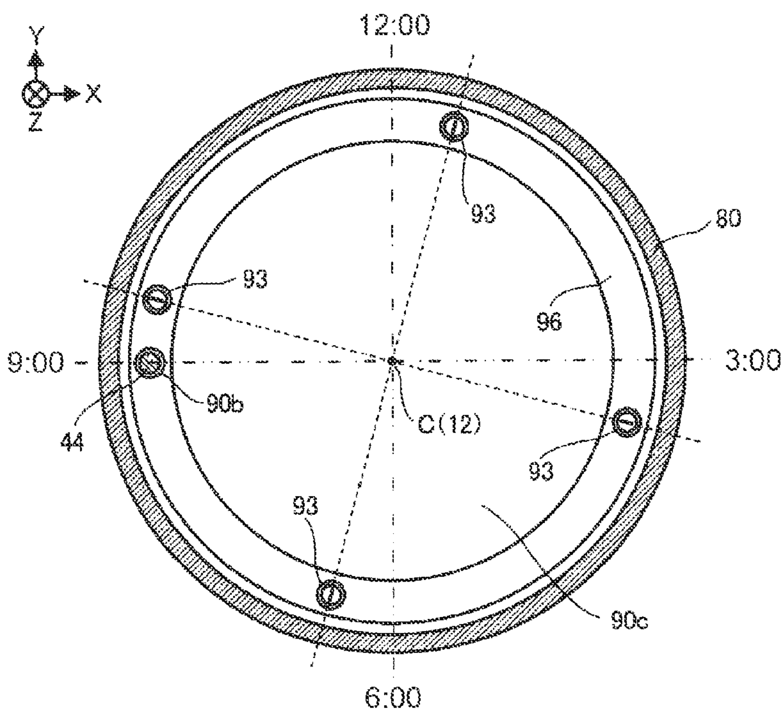

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FIG. 9

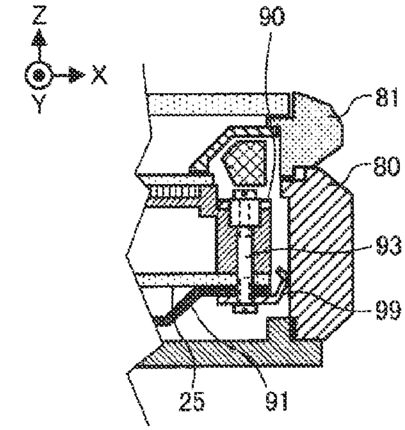


FIG.10

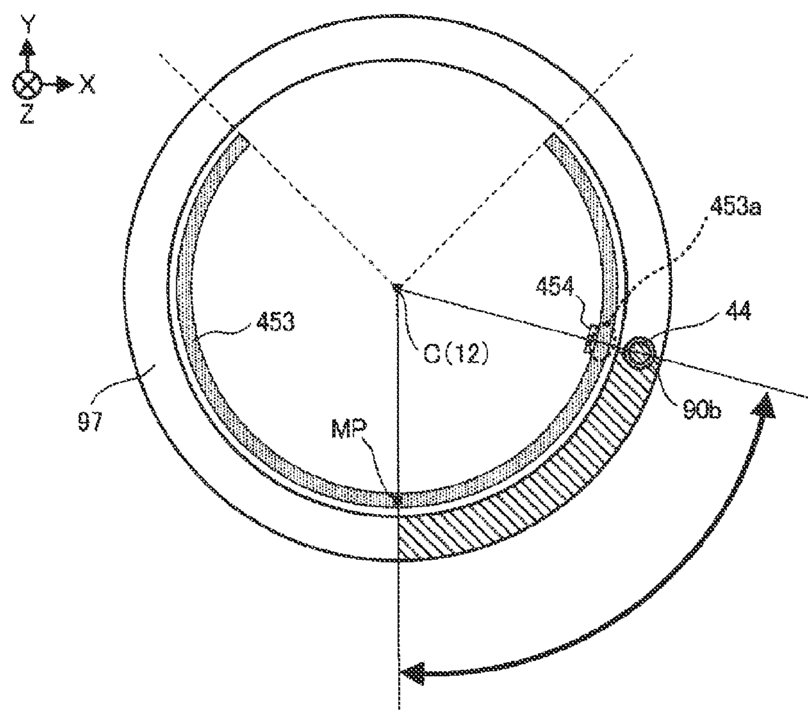
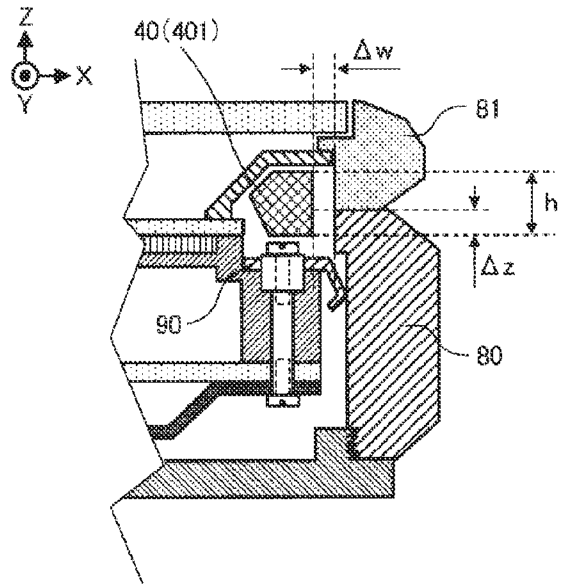


FIG.11



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X
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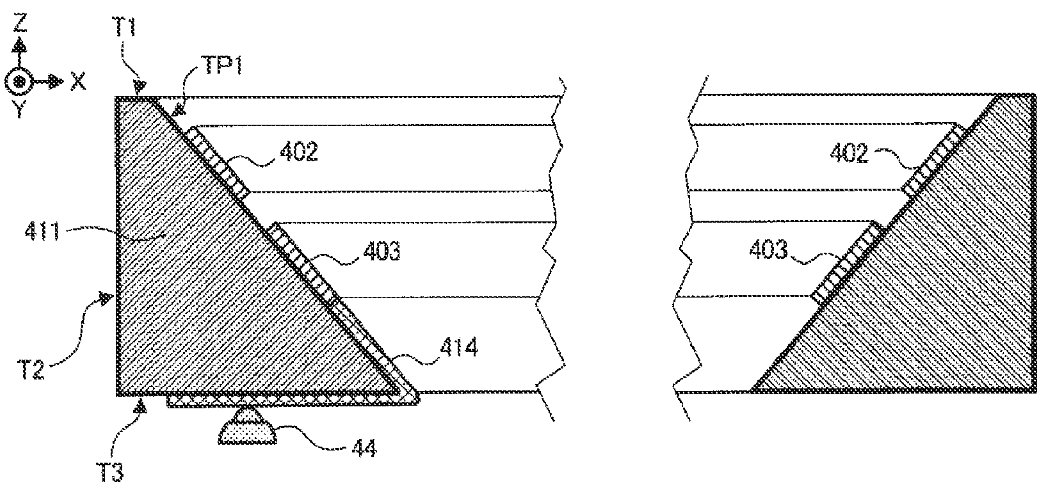
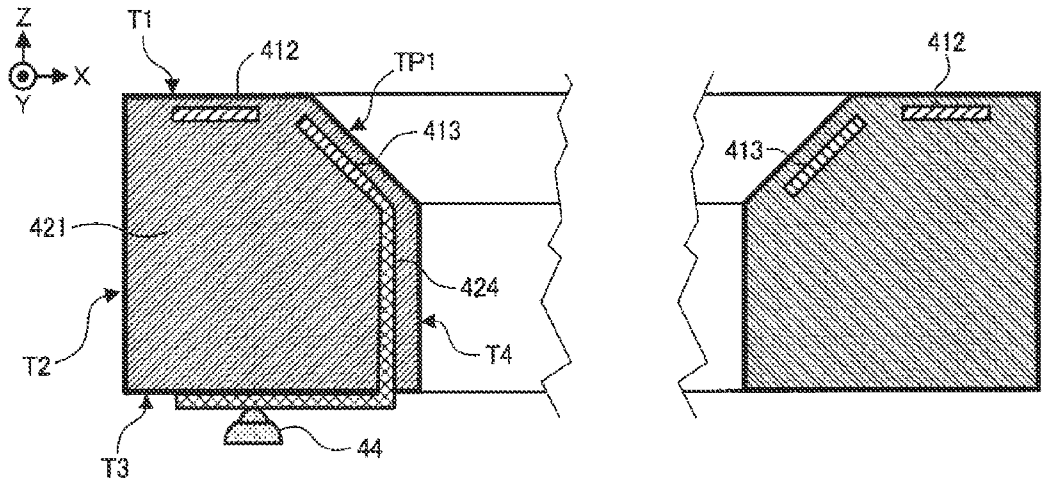
40(401)
Δw
81
h
Δz
90
80

FIG.12



Z
X
Y
T1
TP1
402
411
403
T2
414
T3
44
402
403

FIG.13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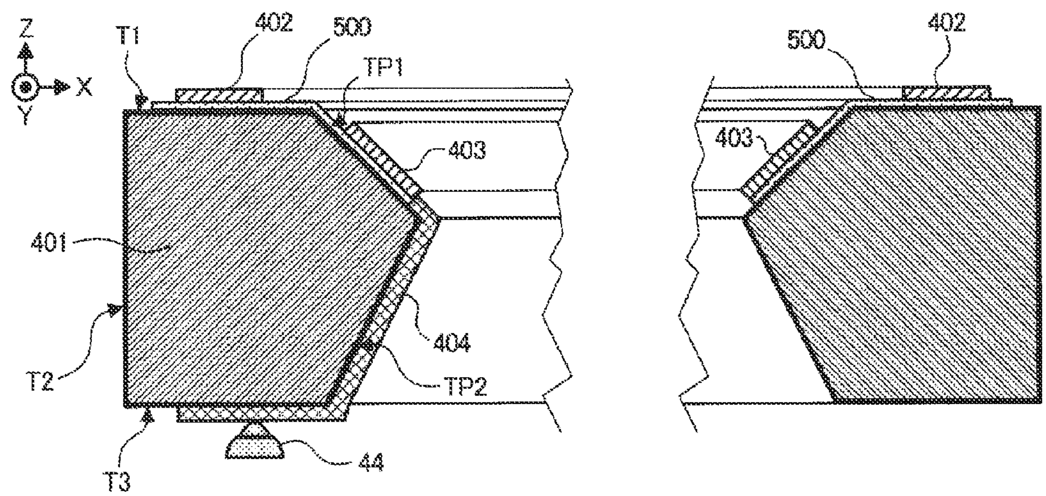
T1
412
TP1
413
421
424
T2
T4
T3
44
412
413

FIG.14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T1
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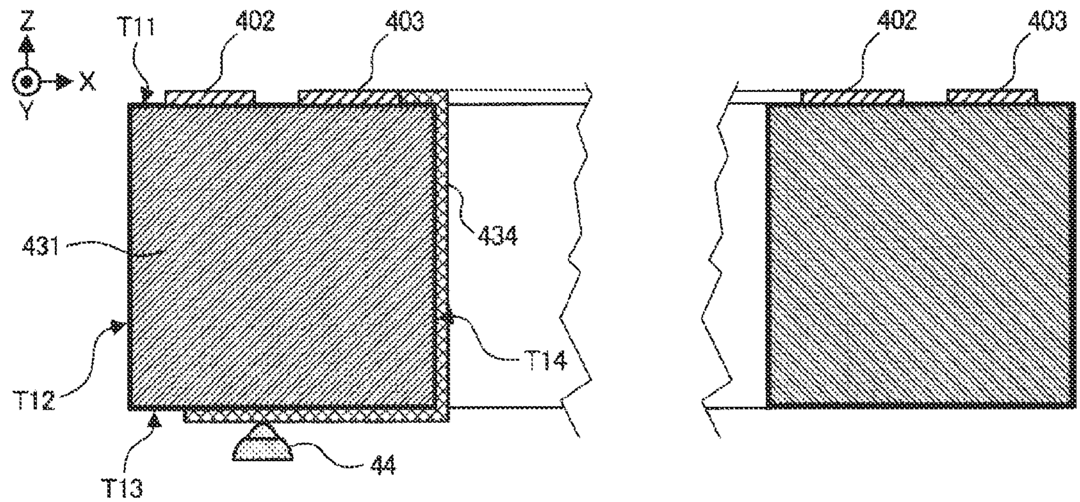
TP1
403
401
404
T2
TP2
T3
44
500
402
403

FIG.15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T11
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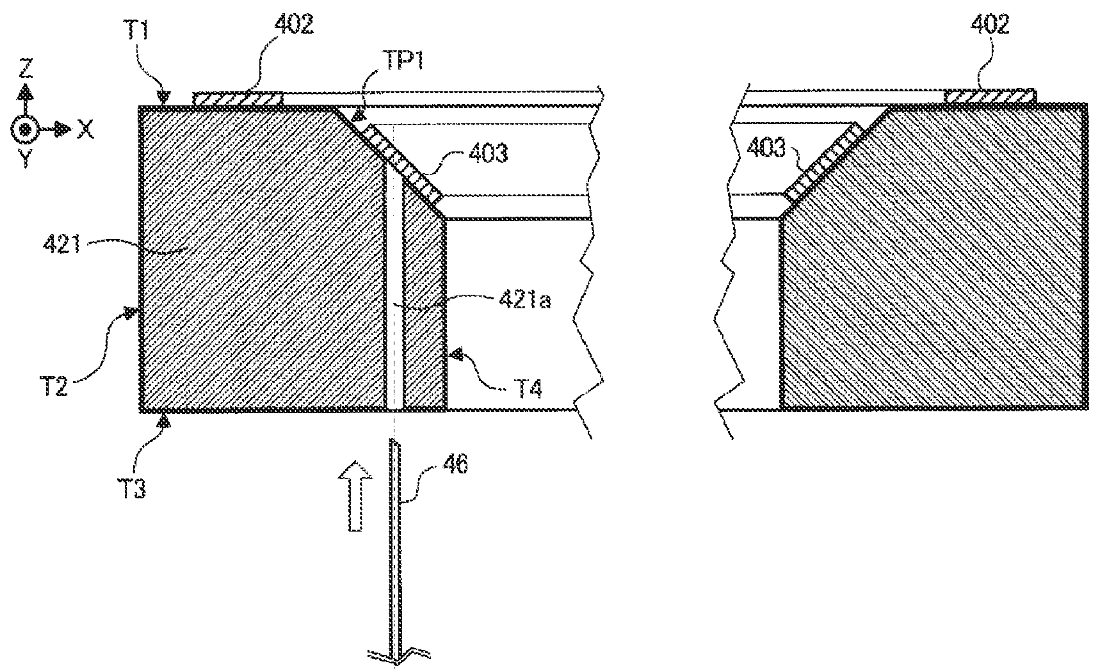
402
403
434
431
T14
T12
T13
44

FIG.16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402
Z
X
Y
403
403
421
421a
T2
T4
T3
46

FIG.17

FIG.18A

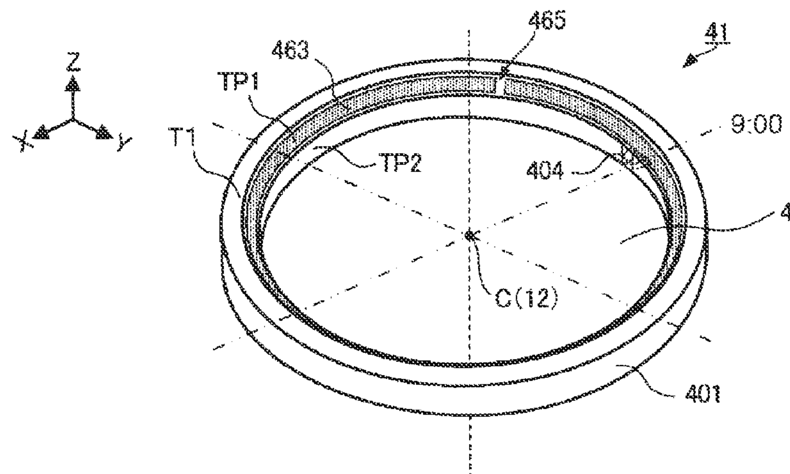
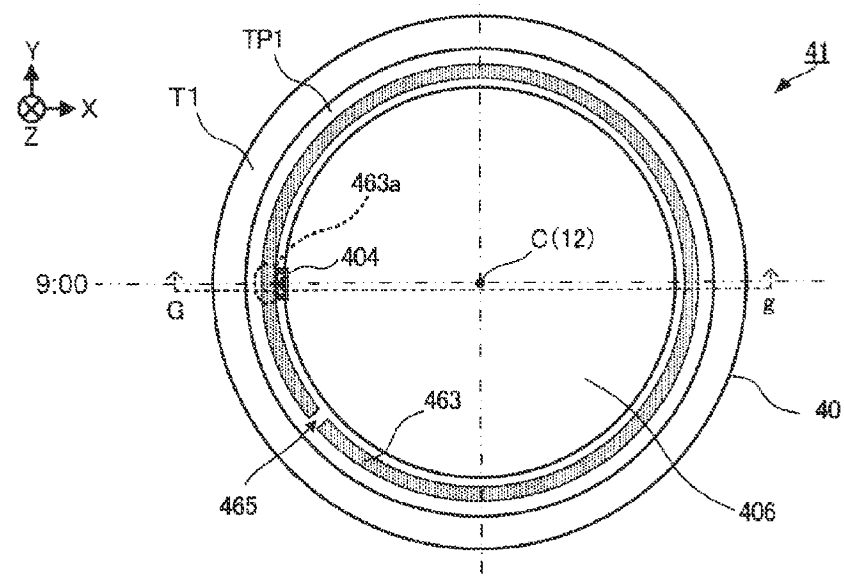


FIG.18B



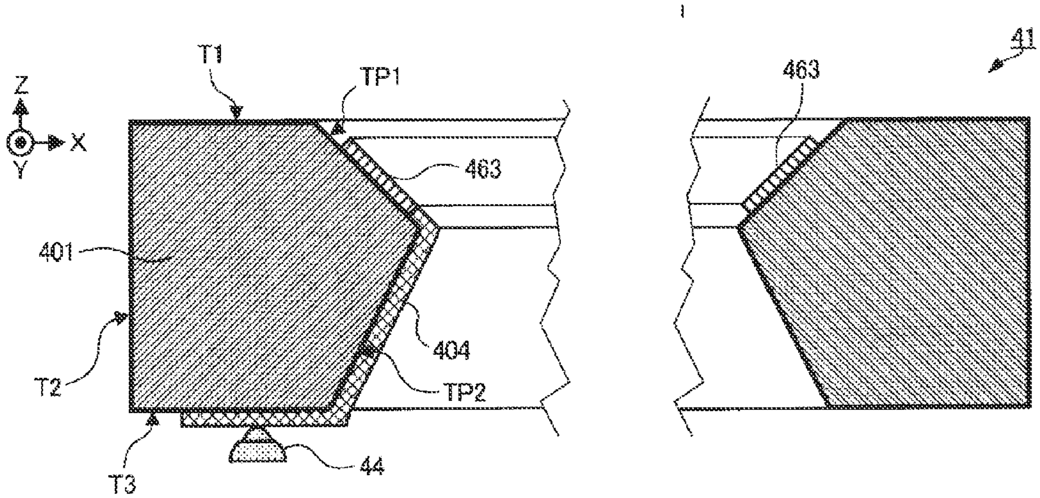


FIG.18C

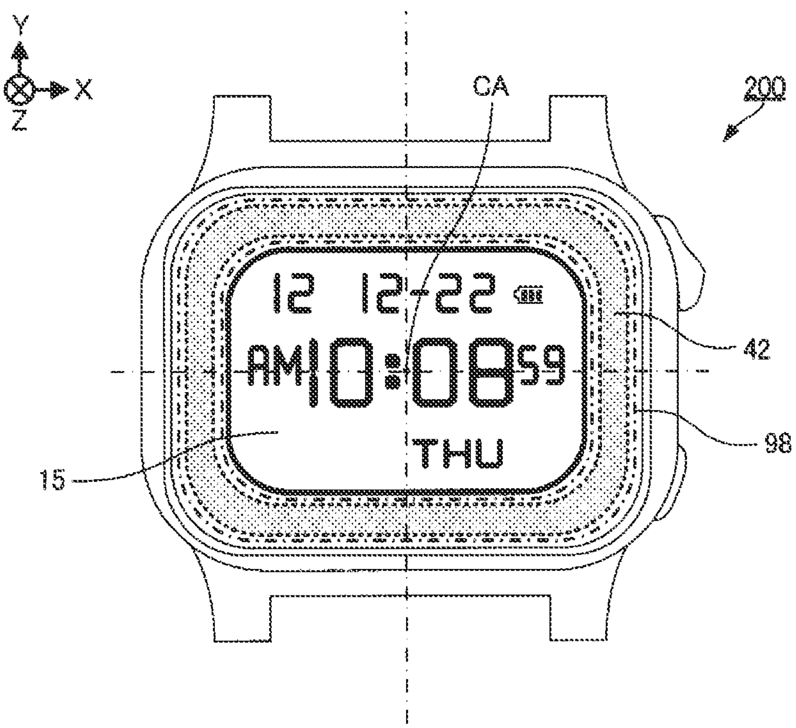


FIG.19

ELECTRONIC TIMEPIECE WITH INTERNAL ANTENNA

BACKGROUND

1. Technical Field

The present invention relates to an electronic timepiece with an internal antenna.

2. Related Art

Japanese Unexamined Patent Appl. Pub. JP-A-2011-021929 discloses a GPS (Global Positioning System) wristwatch 1 that has an annular antenna 11 and a round solar panel support substrate 120 disposed directly below the antenna 11. As shown in FIG. 4 of JP-A-2011-021929, the antenna 11 has an annular dielectric substrate 111, and a conductive antenna electrode 112 (including an antenna body 113, coupling part 114, and feed part 115) formed on the surface of the dielectric substrate 111. The solar panel support substrate 120 is a conductive substrate that supports the dial 2 and solar panel 120A, and functions as a ground plane connected to a connection terminal of a circuit board 25.

The wristwatch 1 disclosed in JP-A-2011-021929 causes the annular antenna body 113 formed on the surface of the dielectric substrate 111 and the solar panel support substrate 120 (ground plane) to resonate, and receives signals from GPS satellites. Because the induced EMF increases as the magnetic flux passing through the plane of the loop increases, the reception performance of the loop antenna increases. However, because the open part of the annular dielectric substrate 111 is blocked directly below the dielectric substrate 111 by the round solar panel support substrate 120 connected to the ground terminal, little magnetic flux passes through the loop plane and the reception performance of the antenna is reduced.

SUMMARY

The present invention is directed to the foregoing problem, and an object of the invention is to improve the reception performance of the antenna in an electronic timepiece with an internal antenna that receives signals by resonance between a ground plane and a driven element disposed on a dielectric.

To achieve the foregoing object, an electronic timepiece with an internal antenna according to the invention has a case; a time display unit that is housed in the case and displays time; an annular dielectric body that is housed in the case and has disposed thereto a conductive driven element to which a specific potential is supplied; and a conductive ground plane with an annular shape that is housed in the case and supplied with ground potential; wherein the dielectric body and the ground plane are disposed coaxially to the same center axis with the gap therebetween in the axial direction less than or equal to the thickness of the dielectric in the axial direction.

Because the ground plane and the dielectric in this aspect of the invention are both annular, the inside part of the rings is open. The ground plane and the dielectric with the driven element disposed thereto are coaxial, and the distance therebetween in the axial direction is less than or equal to the thickness of the dielectric in the axial direction. Because the ground plane and dielectric are disposed in the axial direction with at least part of the openings therein overlapping, the opening in the dielectric is not blocked by the ground plane. The magnetic flux passing through the loop plane of the loop antenna can therefore be increased, and the reception performance of the antenna can be increased, compared with the configuration disclosed in JP-A-2011-021929.

The time display unit may indicate the time by rotating hands on a center pivot over a dial, or have an LCD panel with a display area of a size equal to the dial and display the time by displaying an image of a dial and hands in the display area, or display time digitally on an LCD panel, for example.

Annular means a shape like an endless ring with no break therein, and the shape of the ring could be round, oval, rectangular, or other polygon.

The driven element may be formed on the surface of the dielectric by plating or a silver paste printing process, or embedded in the dielectric by insert molding, for example.

In an electronic timepiece with internal antenna according to another aspect of the invention, the ground plane preferably has a plurality of supply parts to which the ground potential is supplied. These supply parts are, for example, conductive pins or conductive springs.

To produce resonance between the driven element and ground plane and receive a radio signal, holding the potential difference between the driven element and ground plane constant is important, and the stability of the ground potential in the ground plane greatly affects the sensitivity and directivity of the antenna. More particularly, when the shape of the ground plane is a ring, the distribution of the ground potential in the ground plane can easily become uneven if there is only one supply part, leading to a loss of reception performance and variation in directivity. By disposing plural supply parts on the ground plane, this aspect of the invention solves this problem and stabilizes the ground potential in the ground plane. The reception performance of the antenna can therefore be improved, and good directivity can be maintained.

In an electronic timepiece with internal antenna according to another aspect of the invention, the plural supply parts are disposed at equal angles from the center of the ground plane ring. Because this configuration also stabilizes the ground potential in the ground plane, the reception performance of the antenna can therefore be improved, and good directivity can be assured.

In an electronic timepiece with internal antenna according to another aspect of the invention, the driven element is an endless ring or a ring with a notch therein, and has one driven part to which the specific potential is fed; and when the dielectric and ground plane are seen in plan view from the axial direction of the ring, the plural supply parts are disposed symmetrically (line symmetrically) to a line joining the center of the ground plane ring and the driven part.

This configuration also stabilizes the ground potential in the ground plane, and can therefore improve the reception performance of the antenna, and assure good directivity.

More specifically, by disposing plural supply parts symmetrically to a line joining the center of the annular ground plane and the driven part, delay in high frequency components in the driven element can be reduced symmetrically on both sides of the driven part, and good directivity can be assured in the antenna.

In an electronic timepiece with internal antenna according to another aspect of the invention, the driven element is a ring with a notch therein, and has one driven part to which the specific potential is fed; a supply part to which the ground potential is supplied is disposed to one place on the ground plane; and when the dielectric and ground plane are seen in plan view from the axial direction of the ring, the supply part is disposed to a part in a range from the midpoint between the ends of the driven element and the driven part.

To produce desirable resonance between the driven element that is shaped like a ring with a notch therein (such as C-shaped), and the annular (such as O-shaped) ground plane, stabilizing the ground potential in the part of the ground plane overlapping the driven element is important. Therefore, when there is only one supply part disposed to the ground plane, the supply part is preferably in the area of the ground plane overlapping the driven element, such as disposing the supply part at the part corresponding to the midpoint between the ends of the driven element. Furthermore, considering delay of the high frequency component in the driven element, if the driven element is divided into two parts by the driven part, the supply part is preferably disposed to the long side.

Based on the above, when only one supply part is disposed to the ground plane, the ground potential in the part of the ground plane superimposed with the driven element can be efficiently stabilized by disposing the supply part to the part corresponding to the area from the midpoint between the ends of the driven element to the driven part when the dielectric and ground plane are seen in plan view from the axial direction of the ring. The reception performance of the antenna can therefore be improved and good directivity can be assured.

In an electronic timepiece with internal antenna according to another aspect of the invention, the case has a conductive case body that has a cylindrical shape and is supplied with the ground potential; the gap between the inside surface of the case body and the outside surface of the dielectric is less than or equal to the thickness of the dielectric; and the overlap of the case body and the dielectric in the axial direction is greater than or equal to ⅕ the thickness of the dielectric.

This aspect of the invention can increase the reception performance of the antenna and assure good directivity because the driven element can be made to resonate with both the ground plane and the case. The size of the ground plane can also be reduced because the case is also a resonator.

In an electronic timepiece with internal antenna according to another aspect of the invention, the case has a conductive case body with a cylindrical shape, and a conductive back cover connected to the case body; and the ground potential is also supplied to the case body and the back cover.

This aspect of the invention can also improve the reception performance of the antenna because the case body and back cover of the outside case also function as a ground plane, and reflect radio signals entering from the opposite side as the back cover to the antenna (dielectric and driven element) in an electronic timepiece with internal antenna.

In an electronic timepiece with internal antenna according to another aspect of the invention, a conductive parasitic element that is an endless ring or a ring with a notch therein is disposed to the dielectric with a gap to the driven element.

Like the driven element, the parasitic element may be formed on the surface of the dielectric by plating or a silver paste printing process, or embedded in the dielectric by insert molding, for example.

In this aspect of the invention, the driven element and parasitic element are disposed with space therebetween to an annular dielectric. Because current is also induced in the parasitic element when current flows to the driven element, the driven element and parasitic element couple electromagnetically, and together function as an antenna element that converts electromagnetic waves to current. For example, the length of the driven element disposed to the dielectric can be set appropriately by setting the length of the parasitic element disposed to the dielectric to resonate to the radio signals to be received. The impedance of the antenna (dielectric, driven element, and parasitic element), and the circuit electrically connected to the antenna, can also be easily matched.

Furthermore, by electromagnetically coupling the parasitic element to the driven element, the resonance frequency of the antenna can be reduced and the impedance characteristic improved. Return loss at the resonance frequency can therefore be reduced, and the reception performance of the antenna to the radio signals to be received can be increased by matching the resonance frequency of the antenna to the signals to be received.

Other objects and attainments together with a fuller understanding of the invention will become apparent and appreciated by referring to the following description and claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows the configuration of a time adjustment system using the GPS system.

FIG. **2** is a plan view of an electronic timepiece.

FIG. **3** is a section view showing main parts of the electronic timepiece.

FIG. **4** is an exploded oblique view of main parts of the electronic timepiece.

FIG. **5** is a plan view showing the ground plane and casing.

FIG. **6**A to FIG. **6**C are used to describe the structure of the antenna.

FIG. **7** is a block diagram showing the circuit configuration of the electronic timepiece.

FIG. **8** is a plan view showing the ground plane and casing in variation 1 of the preferred embodiment.

FIG. **9** is a plan view showing the ground plane and casing in variation 2 of the preferred embodiment.

FIG. **10** shows a variation of the location of a conductive spring.

FIG. **11** is a plan view showing the ground plane and a C-shaped driven element in variation 4 of the preferred embodiment.

FIG. **12** is a section view showing main parts of an electronic timepiece in variation 5 of the preferred embodiment.

FIG. **13** is a section view of the antenna in variation 7 of the preferred embodiment.

FIG. **14** is a section view of the antenna in variation 8 of the preferred embodiment.

FIG. **15** is a section view of the antenna in variation 9 of the preferred embodiment.

FIG. **16** is a section view of the antenna in variation 10 of the preferred embodiment.

FIG. **17** is a section view of the antenna in variation 12 of the preferred embodiment.

FIG. **18**A to FIG. **18**C are used to describe the structure of the antenna in variation 13 of the preferred embodiment.

FIG. **19** is a plan view of the electronic timepiece in variation 15 of the preferred embodiment.

DESCRIPTION OF EMBODIMENTS

Preferred embodiments of the present invention are described below with reference to the accompanying figures. Note that the size and scale of parts shown in the figures differ from the actual size and scale for convenience. Furthermore, the following examples are specific preferred embodiments of the invention and describe technically desirable limitations, and the scope of the invention is not limited thereby unless such limitation is specifically stated below.

FIG. **1** shows the general configuration of a time adjustment system using the GPS system.

The electronic timepiece **100** is a wristwatch that receives signals (radio signals) from GPS satellites **20** and adjusts the time based thereon, and displays the time on the surface (side) (referred to below as the "face") on the opposite side as the surface (referred to below as the "back") that contacts the wrist.

Each GPS satellite **20** is on a semi-geosynchronous orbit, and transmits a C/A (Coarse/Acquisition) code and navigation messages superimposed on a 1.57542 GHz RF signal (L1 signal). The 1.57542 GHz signal carrying a C/A code and navigation message is referred to herein as simply a "satellite signal." These satellite signals are right-handed circularly polarized waves.

A C/A code is a 1023-bit pseudorandom noise code unique to a specific GPS satellite **20**. Each GPS satellite **20** carries an atomic clock, and the highly precise time information ("GPS time information" below) kept by the atomic clock is included in the navigation message as the time that the satellite signal was transmitted by the GPS satellite **20**. The time difference of the atomic clock onboard each GPS satellite **20** is measured by the ground control segment, and a time correction parameter for correcting this time difference is also included in the navigation message. Precise orbit information (ephemeris) for the GPS satellite **20**, general orbit information (almanac) for all GPS satellites **20** in the constellation, a UTC offset value indicating the offset between UTC (Coordinated Universal Time) and the GPS time, and an ionospheric correction parameter are also included in the navigation message.

After spectrum spreading of the navigation message with the C/A code, the GPS satellite **20** produces a satellite signal by BPSK (binary phase shift keying) modulation multiplying the spread-spectrum signal with the 1.57542 GHz carrier. The electronic timepiece **100** extracts the navigation message from the received satellite signal by reversing the flow of satellite signals generation by the GPS satellite **20** (demodulating the BPSK modulated signal, then spread-spectrum despreading). Because the C/A code used for spectrum spreading is different for each GPS satellite **20**, the electronic timepiece **100** can determine from which GPS satellite **20** the signal was received.

The electronic timepiece **100** can accurately adjust the time kept by the electronic timepiece **100** (below, the "internal time") to the correct current time using the GPS time information and time correction parameter contained in the satellite signals received from a single GPS satellite **20**.

The electronic timepiece **100** can also acquire positioning information (location information such as the latitude and longitude) indicating the current location of the electronic timepiece **100** by receiving satellite signals from at least three (normally four) or more GPS satellites **20** and extracting the GPS time information and orbit information (ephemeris) of each GPS satellite **20** contained in the received signals. The acquired positioning information can also be used to adjust the time zone.

The electronic timepiece **100** also calculates the distance to each GPS satellite **20** from the difference between the time that the satellite signal was received (arrival time) and the transmission time contained in the satellite signal, and calculates the current location of the electronic timepiece **100** by triangulation based on the distance to three or more GPS satellites **20**. The electronic timepiece **100**, however, uses a crystal oscillator, and cannot keep time as precisely as an atomic clock. A time error as short as one-millionth of a second results in a distance error of approximately 300 meters. As a result, the electronic timepiece **100** normally receives satellite signals from four or more GPS satellites **20** to correct the internal time while acquiring positioning information.

FIG. **2** is a plan view of the electronic timepiece **100**.

As shown in FIG. **2**, the electronic timepiece **100** has a cylindrical outside case **80** made of metal or other conductive material. An annular bezel **81** made of a non-conductive material such as ceramic or plastic is fit to the top (face side) of the case **80**, and the opening in the bezel **81** is covered by a transparent crystal **84**.

An annular dial ring **83** made of a non-conductive material such as ceramic or plastic is disposed inside the bezel **81**, and a round dial **11** is disposed inside the dial ring **83**. Bar-shaped hour markers are disposed every 30 degrees around the dial ring **83**, and part of each hour marker protrudes above the top of the dial **11**. Additional minute markers are also inscribed every 6 degrees between adjacent hour markers. The markers could alternatively be disposed on the dial **11**, and the numbers 1 to 12 could be used instead of the bar-shaped hour markers. The appearance of the dial ring **83** and the dial **11** are thus not limited to the appearance shown in the figure.

Hands **13** (second hand **13***a*, minute hand **13***b*, and hour hand **13***c*) that turn on a center pivot **12** and indicate the time, for example, are disposed above the dial **11**. The user can see the dial ring **83**, dial **11**, and hands **13** through the crystal **84**. An annular antenna **40** is disposed below (on the back side of) the dial ring **83**.

The electronic timepiece **100** also has a **16** and buttons **17**, **18**. By manipulating the crown **16** and buttons **17**, **18**, the user can set the electronic timepiece **100** to a time information acquisition mode or positioning information acquisition mode. The time information acquisition mode is an operating mode for receiving satellite signals and acquiring the GPS time information and time correction parameter from at least one GPS satellite **20**, and adjusting the internal time to the correct time. The positioning information acquisition mode is an operating mode for receiving satellite signals from at least three GPS satellites **20** to acquire the current location of the electronic timepiece **100** and adjust the internal time to the correct time reflecting the local time zone. The electronic timepiece **100** can also regularly automatically execute the time information acquisition mode and the positioning information acquisition mode.

The internal structure of the electronic timepiece **100** is described next.

FIG. **3** is a section view showing main parts of the electronic timepiece **100**, and FIG. **4** is an exploded oblique view showing parts of the electronic timepiece **100**.

As shown in FIG. **3**, the annular bezel **81** is fit to the top (face side) of the cylindrical case **80**, and the top opening of the bezel **81** is covered by the round crystal **84**. The opening on the bottom (back side) of the case **80** is covered by a back cover **85** made of stainless steel, titanium, or other conductive material. the case **80** and back cover **85** screw together, for example. The outside case of the electronic timepiece **100** thus includes the case **80**, bezel **81**, crystal **84**, and back cover **85**.

The annular dial ring **83** is disposed to the inside circumference of the bezel **81** below the crystal **84**. The outside circumference side of the dial ring **83** is flat and contacts the inside surface of the bezel **81**, and the inside circumference side is bevelled and slopes to the inside. A donut-shaped storage space is formed below the dial ring **83**, and the annular antenna **40** is housed in this space.

The antenna **40** is disposed on the inside side of the inside circumference of the case **80** and bezel **81**, and the top of the antenna **40** is covered by the dial ring **83**.

An annular ground plane **90** made of metal or other conductive material is disposed below the antenna **40**. As shown in FIG. **4**, four holes are formed in the ground plane **90** in addition to a through-hole **90***b* for the feed pin **44**, and a conductive pin **93** as shown in FIG. **3** is disposed in each of these four holes. Four holes for passing conductive pins **93** are also formed in the main plate **38** and the edge of the circuit board **25** matching the holes in the ground plane **90**. See FIG. **4**.

The ground potential of the circuit block including a GPS reception unit **26** and control unit **70** is supplied through the circuit board **25** to the conductive pins **93**, and the ground potential of the four conductive pins **93** is supplied to the ground plane **90**. Four conductive springs **90***a* are also disposed to the ground plane **90** as shown in FIG. **4**. Part of each conductive spring **90***a* contacts the inside surface of the case **80** with the urging force of the spring (see FIG. **3**), and the conductive springs **90***a* are thereby electrically connected to the case **80**. The ground potential is therefore also supplied through the ground plane **90** (conductive springs **90***a*) to the case **80**.

As described in further detail below, the antenna **40** includes an annular base **401** made of a dielectric material, and a parasitic element **402** and a driven element **403** disposed on the base **401** (see FIG. **6**). As shown in FIG. **4**, the base **401** of the antenna **40** and the ground plane **90** are coaxial to each other and to the center pivot **12**. As shown in FIG. **3**, the gap ⊗d on the z-axis between the base **401** and ground plane **90** is less than or equal to h, where h is the thickness on the z-axis of the base **401** of the antenna **40**. The base **401** of the antenna **40** and the ground plane **90** are thus disposed on the z-axis so that the center axis of each is the same and the distance therebetween on the z-axis is a gap •d of h or less. The gap •d between the antenna **40** (base **401**) and the ground plane **90** is h or less in order to make the ground plane **90** and the driven element **403** disposed to the base **401** resonate and receive radio waves (satellite signals). If this gap ⊗d is too great, the ground plane **90** and driven element **403** will not resonate and signals cannot be received.

The outside circumference of the ground plane **90** is preferably greater than the outside circumference of the base **401** of the antenna **40** in order to make the ground plane **90** and the driven element **403** disposed to the base **401** resonate desirably. The width W**2** of the ground plane **90** on the x-y plane is preferably greater than the width W**1** of the base **401** of the antenna **40** on the x-y plane (FIG. **4**). However, the outside circumference of the ground plane **90** could be less than or equal to the outside circumference of the base **401**, and the width W**2** of the ground plane **90** less than or equal to the width W**1** of the base **401**. If the outside circumference of the ground plane **90** is less than or equal to the outside circumference of the base **401**, however, the width W**2** of the ground plane **90** must be at least ⅓ or more of the width W**1** of the base **401**.

The dial **11** and solar panel **87** are disposed inside the antenna **40**. The dial **11** is made of plastic or other optically transparent non-conductive material.

The solar panel **87** is a round disc having plural solar cells (photovoltaic devices) that convert light energy to electrical energy (power) connected in series. The dial **11** and solar panel **87** are superimposed with each other and have a center hole through which the center pivot **12** passes.

The main plate **38** made of plastic, ceramic, or other non-conductive material is disposed below the solar panel **87**. The center pivot **12** extends through the solar panel **87** and main plate **38** in the thickness direction between the face and back. The center pivot **12** is the center of the electronic timepiece **100** when the electronic timepiece **100** is seen from the direction perpendicular to the dial **11** (that is, when the electronic timepiece **100** is seen in plan view). The hands **13** (**13***a* to **13***c*) are disposed between the crystal **84** and the dial **11** inside the inside circumference of the antenna **40** as shown in FIG. **3**.

A drive mechanism **30** that causes the center pivot **12** to turn and drives the hands **13** is disposed below the main plate **38** as shown in FIG. **3**. The drive mechanism **30** includes a stepper motor M and wheel train, and drives the hands **13** by the stepper motor M causing the center pivot **12** to turn through the wheel train. For example, the hour hand **13***c* turns one revolution in 12 hours, the minute hand **13***b* turns one revolution in 60 minutes, and the second hand **13***a* turns one revolution in 60 seconds. The time display unit includes, for example, the dial **11**, center pivot **12**, hands **13** (**13***a* to **13***c*), and the drive mechanism **30**.

The circuit board **25** is disposed below the main plate **38** and drive mechanism **30**. A circuit block including a GPS reception unit **26** and control unit **70** is disposed on the bottom (on the surface facing the back of the wristwatch) of the circuit board **25**. The GPS reception unit **26** is a single-chip IC module, for example, and includes analog and digital circuits. The control unit **70** controls the operation of the GPS reception unit **26** and drive mechanism **30**. A storage battery **27** is disposed on the bottom of the circuit board **25** (FIG. **3**). The storage battery **27** in this embodiment is a lithium ion battery, and is charged by the power produced by the solar panel **87**.

A wiring pattern for supplying the ground potential, and a wiring pattern for supplying a specific potential to feed the antenna **40**, are formed on the circuit board **25**. The feed pin **44** is a pin connector made of metal or other conductive material, and has an internal coil spring. As shown in FIG. **4**, the feed pin **44** is electrically connected through through-holes **38***a*, **90***b* in the main plate **38** and ground plane **90** to the top of the circuit board **25** and the bottom of the antenna **40**. The top end of the feed pin **44** contacts the bottom of the antenna **40** (more specifically, the coupling part **404** described below) due to the urging force of the coil spring. The bottom of the feed pin **44** likewise contacts the top of the circuit board **25** (more specifically, the part where the wiring pattern supplying a specific potential is formed) due to the urging force of the coil spring. A specific potential is fed to the antenna **40** through the feed pin **44**.

The GPS reception unit **26** and control unit **70** are covered by a shield **91** made of metal or other conductive material as shown in FIG. **3**. The ground potential is supplied to the shield **91**, and the ground potential is further supplied through the shield **91** and a metal circuit support **39** to the back cover **85** and case **80**. The ground potential is also supplied through the circuit board **25** and conductive pins **93** to the ground plane **90** and case **80**. The ground potential is thus supplied to the ground plane **90** on a path through the circuit board **25** and conductive pins **93**, and ground potential is also supplied on a path through the shield **91**, circuit support **39**, back cover **85**, case **80**, and conductive springs **90***a*. Of the outside case members through which the ground potential is supplied, the case **80** and back cover **85** also function as a ground plane, and reflect satellite signals entering from the crystal **84** to the antenna **40**.

The members constituting the ground potential supply path (such as the shield **91**, circuit support **39**, back cover **85**, conductive pin **93**, ground plane **90**, and conductive springs **90***a*) are processed with gold plating or anticorrosion coating on the contact surfaces between the members. The conductive pins **93** are screwed tight. Contact resistance between the members of the ground potential supply path can therefore be held as low as possible for a long time.

FIG. **5** is a plan view of the ground plane **90** and case **80**.

The through-hole **90***b* through which the feed pin **44** passes is formed in the ground plane **90** at the 9:00 position relative to the center C of the ground plane **90** ring. Four conductive pins **93** are attached to the ground plane **90** at equiangular (90 degree) positions around the center C. Four conductive springs **90***a* formed in unison with the ground plane **90** are also disposed at equiangular (90 degree) positions around the center C in the outside edge of the ground plane **90**. Part of each conductive spring **90***a* contacts the inside circumference surface of the case **80** due to the urging force of the spring, and the ground potential is therefore also supplied from the case **80** through the conductive springs **90***a* to the ground plane **90**. The ground plane **90** also has an opening **90***c* in the center.

Including the conductive pins **93** and conductive springs **90***a*, there are thus 8 supply parts through which the ground potential is supplied to the ground plane **90**. The ground potential can therefore be stabilized in the ground plane **90**. The stability of the ground potential can also be increased when the electronic timepiece **100** is worn on the wrist because the body also acts as a ground through the back cover **85** and case **80**.

FIG. **6**A to FIG. **6**C describe the construction of the antenna **40**.

FIG. **6**A is an oblique view of the antenna **40**, FIG. **6**B is a plan view of the antenna **40**, and FIG. **6**C is a section view of the antenna **40** through line G-g in FIG. **6**B.

The antenna **40** includes an annular base **401** made of plastic, ceramic, or other dielectric material, a parasitic element **402** formed on the surface of the base **401**, a driven element **403**, and a coupling part **404**. The base **401** has a round opening **406** in the center. The parasitic element **402**, driven element **403**, and coupling part **404** are each made of metal or other conductive material, and can be formed by a plating or silver paste printing process. The dielectric constant of the base **401** material can be adjusted to approximately 5-20 by mixing a dielectric material that is used in high frequency applications, such as titanium oxide, with resin.

As shown in FIG. **6**C, the base **401** has a pentagonal section including a top T**1**, outside face T**2**, bottom T**3**, slope TP**1**, and slope TP**2**. The parasitic element **402** is formed on the top T**1**, and the driven element **403** is formed on slope TP**1**. The coupling part **404** is formed on the slope TP**1**, slope TP**2**, and bottom T**3**. The end of the coupling part **404** on the slope TP**1** side connects to the driven element **403**, and the end on the bottom T**3** side contacts the top of the feed pin **44**. A specific potential is therefore supplied through the feed pin **44** and coupling part **404** to the driven element **403**. Potential from an external source is not supplied to the parasitic element **402**.

As shown in FIG. **6**A and FIG. **6**B, the parasitic element **402** is annular, that is, is formed in an endless O-shape. The driven element **403**, however, has a notch **405**, and is therefore C-shaped with part of the ring missing. The driven element **403** has an antenna length that resonates to signals (satellite signals) from a GPS satellite **20**. For example, if the angle between the coupling part **404** and notch **405** is √a, the length of the notch **405** is •s, the circumferential length of the driven element **403** is L, and the free space wavelength of the received circularly polarized waves is •, then L=1.31•, •a=40°, and ⊗ s=0.018•.

The coupling part **404** is connected to an end of the C-shaped driven element **403**. As shown in FIG. **6**B, the part (end) of the driven element **403** to which the coupling part **404** is connected is a driven part **403***a* to which a specific potential is supplied. Note that the driven part **403***a* is not limited to being disposed to an end of the driven element **403**, and can be at a part of the driven element **403** other than an end.

The driven part **403***a* is also disposed at approximately the 9:00 position of the electronic timepiece **100**. More specifically, when the electronic timepiece **100** is seen in plan view, the driven part **403***a*, coupling part **404**, and feed pin **44** are disposed at 9:00 relative to the center (center pivot **12**) of the electronic timepiece **100**. However, the location of the driven part **403***a*, coupling part **404**, and feed pin **44** is not limited to 9:00 from the center of the electronic timepiece **100**, and could be at 8:00, 10:00, 5:00, or 1:00, for example.

As shown in FIG. **6**A and FIG. **6**B, the parasitic element **402** and driven element **403** are disposed with a specific gap therebetween, and when current flows to the driven element **403**, current is induced in the parasitic element **402**. That is, the distance between the parasitic element **402** and driven element **403** is a distance enabling electromagnetic coupling therebetween. The driven element **403** and parasitic element **402** therefore couple electromagnetically, and together function as an antenna element that converts electromagnetic waves to current. Because the parasitic element **402** is O-shaped, the antenna **40** overall functions as an O-shaped loop antenna. The driven element **403** to which a specific potential is supplied and the ground plane **90** to which ground potential is supplied therefore resonate, and the electronic timepiece **100** can receive radio waves (satellite signals) from a GPS satellite **20**.

Because GPS satellites **20** transmit satellite signals at 1.575 GHz, one wavelength is approximately 19 cm. Because an antenna length of approximately 1.0-1.2 wavelength is required to receive circularly polarized waves, a loop antenna of approximately 19-24 cm is required to receive a satellite signal. Rendering a loop antenna with this antenna length in a wristwatch, however, results in a large wristwatch.

For example, if the dielectric constant is •r and a base **401** with a dielectric constant of Σr is used, the wavelength shortening rate of the base **401** will be 1/√Σr. More specifically, the wavelength of the radio waves to be received by the antenna **40** can be shortened 1/√Σr times by using a dielectric with a dielectric constant of •r. As described above, because the dielectric constant •r of the base **401** is approximately 5-20, the antenna length of the antenna **40** can be shortened approximately 0.224 (Σr=20) to 0.447 (•r=5) times compared with a configuration not using the base **401**.

The resonance frequency of the antenna **40** can also be reduced and the impedance characteristic can be improved by electromagnetically coupling the parasitic element **402** to the driven element **403**. Return loss at the resonance frequency can therefore be reduced, and the satellite signal reception performance of the antenna **40** can be increased by adjusting the resonance frequency of the antenna **40** to the satellite signal.

Note that contact resistance can be kept low for a long time and a drop in the reception performance of the antenna **40** can be prevented by also applying gold plating or anticorrosion coating process to the contact surfaces of the feed pin **44** and coupling part **404**, and the contact surfaces of the feed pin **44** and circuit board **25**.

FIG. **7** is a block diagram showing the circuit configuration of the electronic timepiece **100**.

The electronic timepiece **100** includes a GPS reception unit **26** and a control display unit **36**. The GPS reception unit **26** executes processes related to receiving satellite signals, locking onto GPS satellites **20**, generating positioning information, and generating time adjustment information, for example. The control display unit **36** executes processes including keeping and adjusting the internal time, and movement of the hands **13**.

A solar panel **87** charges the storage battery **27** through the charging control circuit **29**. The storage battery **27** supplies drive power through a regulator **34** to the control display unit **36**, and supplies drive power through another regulator **35** to the GPS reception unit **26**. A voltage detection circuit **37** detects the voltage of the storage battery **27** and outputs to a control unit **70**.

Regulator **35** could be split into a regulator that supplies drive power to the RF (radio frequency) unit **50**, and a regulator that supplies drive power to a baseband unit **60**. In this case, the regulator that supplies power to the RF unit **50** could be disposed in the RF unit **50**.

A rated potential generator **33** generates a specific potential with a predetermined potential difference to ground. The specific potential generated by the rated potential generator **33** is supplied through the circuit board **25** and feed pin **44** to the antenna **40** (driven element **403**).

The antenna **40** receives satellite signals from GPS satellites **20**. However, because some extraneous signals other than the desired satellite signals are also received, a SAW (surface acoustic wave) filter **32** is disposed after the antenna **40**. The SAW filter **32** functions as a bandpass filter that passes signals in the 1.5 GHz waveband, and extracts the satellite signal from the signals received by the antenna **40**.

The GPS reception unit **26** includes the RF unit **50** and baseband unit **60**. The RF unit **50** includes a LNA (low noise amplifier) **51**, mixer **52**, VCO (voltage controlled oscillator) **53**, PLL (phase-locked loop) circuit **54**, IF (intermediate frequency) amplifier **55**, IF filter **56**, and A/D converter **57**.

Signals (satellite signals) passed by the SAW filter **32** are input to the RF unit **50** and amplified by the LNA **51**. The satellite signal amplified by the LNA **51** is mixed by the mixer **52** with the clock signal output by the VCO **53**, and down-converted to a signal in the intermediate frequency band. The PLL circuit **54** phase compares a clock signal obtained by frequency dividing the output clock signal of the VCO **53** with a reference clock signal supplied from the baseband unit **60**, and synchronizes the output clock signal of the VCO **53** to the reference clock signal. As a result, the VCO **53** can output a stable clock signal with high frequency precision. Note that several megahertz, for example, can be selected as the intermediate frequency.

The signal in the IF band output from the mixer **52** is amplified by the IF amplifier **55**. However, because mixing by the mixer **52** produces a high frequency component of several GHz, the IF amplifier **55** amplifies both the IF signal and the high frequency component of several GHz. As a result, the IF filter **56** extracts the IF signal and removes the high frequency component (more accurately, attenuates the signal to a specific level or less). The IF signal passed by the IF filter **56** is converted to a digital signal by the A/D converter **57**.

The baseband unit **60** includes, for example, a DSP (digital signal processor) **61**, CPU (central processing unit) **62**, SRAM (static random access memory) **63**, and RTC (real-time clock) **64**. A TCXO (temperature compensated crystal oscillator) **65** and flash memory **66** are also connected to the baseband unit **60**.

The TCXO **65** generates a reference clock signal of a substantially constant frequency regardless of temperature. Operation of the baseband unit **60** is synchronized to the reference clock signal output by the TCXO **65**. The RTC **64** generates the timing for satellite signal processing, and counts up at the reference clock signal output from the TCXO **65**.

Time zone information, for example, is stored in flash memory **66**. The time zone information defines the time difference to UTC related to known coordinates (such as latitude and longitude).

The baseband unit **60** executes a process that demodulates the baseband signal from the digital signal (IF signal) output from the A/D converter **57** of the RF unit **50** when the time information acquisition mode or the positioning information acquisition mode is set.

In addition, when the time information acquisition mode or the positioning information acquisition mode is set, the baseband unit **60** executes a process that generates a local code of the same pattern as each C/A code, and correlates the local codes to the C/A code contained in the baseband signal, in the satellite search step. The baseband unit **60** adjusts the timing when the local code is generated to find the peak correlation to each local code, and when the correlation equals or exceeds a threshold value, determines that the local code synchronized with the GPS satellite **20** (that is, locked onto a GPS satellite **20**). Note that the GPS system uses a CDMA (Code Division Multiple Access) method whereby all GPS satellites **20** transmit satellite signals on the same frequency using different C/A codes. The GPS satellites **20** that can be locked onto can therefore be found by identifying the C/A code contained in the received satellite signal.

To acquire the navigation message from the satellite signal of the GPS satellite **20** that was locked onto, the baseband unit **60** also executes a process that mixes the baseband signal with the local code of the same pattern as the C/A code of the GPS satellite **20** that was locked. The navigation message from the GPS satellite **20** that was locked onto is thereby demodulated. The baseband unit **60** then executes a process to detect the TLM word (preamble data) of each subframe in the navigation message, and acquire and store in SRAM **63** satellite information such as the orbit information and GPS time information contained in each subframe. The GPS time information as used here is the week number (WN) and Z count, but the Z count data alone could be acquired if the week number was previously acquired.

The baseband unit **60** then generates the time adjustment information based on the satellite information. The time adjustment information is information for correcting the internal time kept by the electronic timepiece **100**.

In the time information acquisition mode, the baseband unit **60** can generate the time adjustment information using the GPS time information, time adjustment parameter, or UTC offset contained in the satellite information from one GPS satellite **20**, for example. The baseband unit **60** can also generate the time adjustment information from satellite information from a plurality of GPS satellites **20**. The time adjustment information in the time information acquisition mode could be, for example, the GPS time information itself, the GPS time information after being corrected based on the time adjustment parameter, or time information acquired by adding the time adjustment parameter or UTC offset to the GPS time information. Further alternatively, information indicating the difference between this time information and the internal time of the electronic timepiece **100** could be used as the time adjustment information.

However, in the positioning information acquisition mode, the baseband unit **60** receives satellite information from at least three (and normally four) or more GPS satellites **20**, and acquires the location of the electronic timepiece **100** using the received satellite information. Next, the baseband unit **60** references the time difference information stored in flash memory **66**, and acquires the time difference at the acquired location. The baseband unit **60** then adds the acquired time difference to the time adjustment information generated using the same method used in the time information acquisition mode. The time adjustment information used in the positioning information acquisition mode therefore reflects the time difference at the current location of the electronic timepiece **100**.

The control display unit **36** includes a control unit **70**, crystal oscillator **73**, and drive circuit **74**.

The control unit **70** can be rendered by a configuration including a storage unit **71** and a CPU with a RTC (real-time clock) **72**.

The control unit **70** outputs control signals to the GPS reception unit **26**, and controls operation of the GPS reception unit **26**. The control unit **70** also controls movement of the hands **13** (**13***a* to **13***c*) through the drive circuit **74**. The control unit **70** also controls operation of regulators **34**, **35** and the rated potential generator **33** based on output from the voltage detection circuit **37**.

The time adjustment information and positioning information output from the GPS reception unit **26** are stored in the storage unit **71**. The RTC **72** keeps the internal time. The RTC **72** operates continuously, and counts up at the reference clock signal generated by the crystal oscillator **73**. Whether the time information acquisition mode or the positioning information acquisition mode is set, the control unit **70** can therefore continue moving the hands **13** based on the internal time kept by the RTC **72**.

When time adjustment information is output from the GPS reception unit **26** in the time information acquisition mode or the positioning information acquisition mode, the control unit **70** corrects the internal time kept by the RTC **72** according to the time adjustment information. When the internal time is corrected, the control unit **70** also drives the hands **13** through the drive circuit **74** so that the hands **13** (**13***a* to **13***c*) indicate the internal time after being corrected. As a result, the internal time of the electronic timepiece **100** is set to the correct time. In the positioning information acquisition mode, the internal time can also be adjusted to the correct time reflecting the time difference (time zone) at the current location of the electronic timepiece **100**.

In the embodiment of the invention described above, the base **401** (dielectric) of the antenna **40** and the ground plane **90** both have an annular shape, and have an opening **406**, **90***c* on the inside part of the ring. The ground plane **90** is disposed coaxially to the base **401** to which the driven element **403** is disposed, and the gap •d in the axial direction (z-axis) therebetween is less than or equal to the thickness h of the base **401** on the z-axis. In this configuration the base **401** and ground plane **90** are superimposed on the z-axis so that at least part of the openings **406**, **90***c* thereof overlap. As a result, the opening **406** in the base **401** of the antenna **40** is not blocked by the ground plane **90**, and the reception performance of the antenna **40** can be increased compared with the configuration disclosed in JP-A-2011-021929 because the mag flux passing through the loop plane of the loop antenna can be increased.

Plural supply parts (conductive pins **93** and conductive springs **90***a*) to which ground potential is supplied are disposed at equiangular intervals to the center C of the annular ground plane **90** in this embodiment. To produce resonance between the driven element **403** and ground plane **90** and receive a satellite signal, the potential difference between the driven element **403** and ground plane **90** must be held constant, and the stability of the ground potential in the ground plane **90** greatly affects the sensitivity and directivity of the antenna **40**. More particularly, when the shape of the ground plane **90** is a ring, the distribution of the ground potential in the ground plane **90** can easily become uneven if there is a single supply part, resulting in a loss of reception performance and variation in directivity in the antenna **40**. Therefore, by disposing plural supply parts on the ground plane **90** at equiangular positions around the center C, the ground potential in the ground plane **90** can be stabilized, the reception performance of the antenna **40** improved, and good directivity maintained.

The reception performance of the antenna **40** can also be improved in this embodiment because the case **80** and back cover **85** of the outside case function as a ground plane, and reflect satellite signals input from the crystal **84** side toward the antenna **40**.

This embodiment can also lower the resonance frequency of the antenna **40** and improve impedance characteristics by electromagnetically coupling the parasitic element **402** and driven element **403**. Return loss at the resonance frequency can therefore be reduced, and the satellite signal reception performance of the antenna **40** improved, by matching the resonance frequency of the antenna **40** to the satellite signal.

The invention is not limited to the foregoing embodiment, and can be varied in many ways such as described in the following variations. Two or more of the variations described below can also be desirably combined.

Variation 1

FIG. **8** is a plan view showing the ground plane **95** and case **80** in variation 1. In the ground plane **95** according to this variation, plural supply parts (conductive pins **93** and conductive springs **90***a*) are disposed line symmetrically to the line LN between the center C of the ground plane **95** ring and the feed pin **44**. When the antenna **40** is seen in plan view on the z-axis, the position of the feed pin **44** is at the position of the driven part **403***a* of the driven element **403**. The ground potential in the ground plane **95** can also be stabilized, the reception performance of the antenna **40** can be improved, and good directivity can be maintained when plural supply parts are disposed line symmetrically to line LN. More particularly, because delay of the high frequency component in the driven element **403** can be reduced symmetrically on both sides of the driven part **403***a* by providing plural supply parts line symmetrically to line LN, good directivity can be maintained in the antenna **40**.

Variation 2

FIG. **9** is a plan view showing the ground plane **96** and case **80** in variation 2. The ground plane **96** according to this variation differs from the ground plane **90** shown in FIG. **5** in that (4) conductive springs **90***a* are not used. The ground plane **96** can thus be embodied with only the conductive pin **93** parts of the conductive pins **93** and conductive springs **90***a*. Conversely, the ground plane **96** can also be embodied with only the conductive springs **90***a*.

Variation 3

The conductive pins **93** and conductive springs **90***a* are also not limited to four, and there may be one or more. The conductive pins **93** and conductive springs **90***a* are also not limited to equiangular positions from the center C. The conductive springs **90***a* and ground plane **90** can also be separate parts with the conductive springs **90***a* attached to the ground plane **90** using screws or other means. As shown in FIG. **10**, conductive springs **99** discrete from the ground plane **90** can also be affixed by the conductive pins **93** to the bottom of the circuit board **25** together with the shield **91**. The ground plane **90** can also be embodied with a conductive coating formed on the surface of an annular member made of a non-conductive material.

Variation 4

FIG. **11** is a plan view of a ground plane **97** and C-shaped driven element **453** according to variation 4. The driven element **453** is shown inside the ground plane **97** in the figure, but because the base **401** of the antenna **40** is actually disposed above the ground plane **97**, and the driven element **453** is disposed to slope TP**1** of the base **401**, the ground plane **97** and driven element **453** overlap on the z-axis. To produce desirable resonance between the C-shaped driven element **453** disposed to the base **401** and the annular (O-shaped) ground plane **97**, the ground potential must be stable in the part of the ground plane **97** overlapping the driven element **453**. Therefore, when there is only one supply part (conductive pin **93** or conductive spring **90***a*) disposed to the ground plane **97**, the supply part is preferably in the area of the ground plane **97** overlapping the driven element **453**, such as disposing the supply part at the part corresponding to the midpoint MP between the ends of the driven element **453**. Furthermore, considering delay of the high frequency component in the driven element **453**, if the driven element **453** is divided into two parts by the driven part **453***a*, the supply part is preferably disposed to the long side.

Based on the foregoing, when only one supply part is disposed to the ground plane **97**, the conductive pin **93** or conductive spring **90***a* is desirably disposed to the part corresponding to the area from the midpoint MP between the ends of the driven element **453** to the driven part **453***a* (the shaded part in the figure). By thus disposing the supply part, the reception performance of the antenna **40** can be improved and good directivity can be maintained because the ground potential in the part of the ground plane **97** superimposed with the driven element **453** can be efficiently stabilized when only one supply part is disposed to the ground plane **97**.

Variation 5

The electronic timepiece **100** described above receives satellite signals by producing resonance between the driven element **403** and ground plane **90**, but the conductive members to which ground potential is supplied near the antenna **40** include the case **80** in addition to the ground plane **90**. The driven element **403** and the case **80** can therefore be made to resonate. In this implementation the gap ⊗w between the inside circumference surface of the case **80** and the outside circumference surface of the base **401** must be h or less, where h is the thickness on the z-axis of the base **401** (dielectric) of the antenna **40**, as shown in FIG. **12**. The top of the case **80** must also be higher than the bottom of the base **401**, and the overlap ⊗z on the z-axis between the case **80** and the base **401** must be ⅕ or more of the thickness h of the base **401** on the z-axis. Because the case **80** and the ground plane **90** both resonate with the driven element **403** in this configuration, the reception performance of the antenna **40** can be improved and good directivity can be maintained. The size of the ground plane **90** can also be reduced by thus including the case **80** as a resonance component.

Variation 6

In the antenna **40** shown in FIG. **6**, the parasitic element **402** is not limited to an endless O-shape, and like the driven element **403** can be C-shaped with a notch. In this variation the entire antenna **40** functions as a C-shaped loop antenna. The length of the driven element **403** in the foregoing embodiment is also determined to resonate to the satellite signal, but the length of the parasitic element **402** can be set to resonate to the satellite signal. By adjusting the length of the driven element **403** and the position of the notch **405** in this configuration, the impedance between the antenna **40** and the circuit (the circuit block including the GPS reception unit **26** and control unit **70**) electrically connected to the antenna **40** can be easily matched.

Variation 7

FIG. **13** is a section view of the antenna in variation 7, and is the same as the view in FIG. **6**C. The base **411** of the antenna in this variation does not have a slope TP**2**, and slope TP**1** continues to the bottom T**3**. The top T**1** of the base **411** is smaller and the slope TP**1** is larger than the configuration shown in FIG. **6**C. The parasitic element **402** is formed in addition to the driven element **403** on the slope TP**1**, and nothing is disposed to the top T**1**. Both the driven element **403** and parasitic element **402** can thus be disposed to slope TP**1**.

Variation 8

FIG. **14** is a section view of the antenna in variation 8, and is the same as the view in FIG. **6**C. The base **421** of the antenna in this variation has a vertical inside face T**4** instead of a slope TP**2**. All of the parasitic element **412** and the driven element **413**, and part of the coupling part **424**, are embedded in the base **421**. This configuration can be manufactured by insert molding. Insert molding enables manufacturing the antenna at a lower cost than when the parasitic element **402**, driven element **403**, and coupling part **404** are formed on the surface of the base **401** as shown in FIG. **6**C by a plating or silver paste printing process.

Variation 9

FIG. **15** is a section view of the antenna in variation 9, and is the same as the view in FIG. **6**C. As shown in the figure, the parasitic element **402** and driven element **403** are affixed to the base **401** by flexible tape **500**. This configuration can be manufactured, for example, by forming the parasitic element **402** and driven element **403** on flexible tape **500**, and affixing the flexible tape **500** to the surface of the base **401** (top T**1** and slope TP**1**). This manufacturing method enables manufacturing the antenna at a lower cost than when the parasitic element **402** and driven element **403** are formed directly on the surface of the base **401** by a plating or silver paste printing process.

Further alternatively, the coupling part **404** can also be affixed to the base **401** using the flexible tape **500**.

Variation 10

FIG. **16** is a section view of the antenna in variation 10, and is the same as the view in FIG. **6**C. The base **431** of the antenna in this variation is a rectangle with a top T**11**, outside face T**12**, bottom T**13**, and inside face T**14**. The parasitic element **402** and driven element **403** are formed on the top T**11**. The coupling part **434** is formed on the top T**11**, inside face T**14**, and bottom T**13**. The base **431** in this configuration does not need to have a slope TP**1**. The locations of the parasitic element **402** and driven element **403** can also be reversed. More specifically, the driven element **403** can be on the outside of the parasitic element **402**. In this implementation the coupling part **434** is formed on the top T**11**, outside face T**12**, and bottom T**13**. If the coupling part **434** is thus formed on the outside face T**12**, the case **80** is preferably made of a plastic, ceramic, or other non-conductive material.

Variation 11

Instead of using a feed pin **44**, a leaf spring, lead, coaxial cable, or flexible printed circuit can be used to electrically connect the coupling part **404** of the antenna **40** and the circuit board **25**, and supply a specific potential.

Variation 12

FIG. **17** is a section view of the antenna in variation 12, and is the same as the view in FIG. **6**C. The antenna in this variation differs from the antenna **40** shown in FIG. **6** in that (1) the base **421** has a vertical inside face T**4** instead of slope TP**2**, (2) there is no coupling part **404**, and (3) a hole **421***a* is formed from the slope TP**1** to the bottom T**3** of the base **421**. When the antenna according to this variation is used, a rod-shaped feed pin **46** is used instead of the feed pin **44** described above. This feed pin **46** is made of metal or other conductive material, one end is inserted to the hole **421***a*, and the distal end thereof is connected to the driven element **403**. The other end of the feed pin **46** is connected to the wiring pattern on the circuit board **25**, and a specific potential is supplied thereto. With this configuration there is no need to form a coupling part **404** on the surface of the base **421** (dielectric). Disposing a coupling part **404** to the antenna is thus not necessary.

Variation 13

FIG. **18**A to FIG. **18**C show the configuration of an antenna **41** in variation 13. The antenna **41** according to this variation differs from the antenna **40** shown in FIG. **6** in that (1) there is no parasitic element **402**, and (2) the driven part **463***a* is disposed to a part of the driven element **463** other than the end. The antenna can thus be embodied without a parasitic element **402**. This also applies to the antennae shown in FIG. **13** to FIG. **17**. Note, further, that the driven element **463** may be an endless O-shape without a notch **465**.

Variation 14

The second hand **13***a* can be omitted. The time display unit is also not limited to indicating the time by rotating hands **13** over a dial **11**, and could have an LCD panel with a display area of a size equal to the dial **11**, and display the time by displaying an image of a dial **11** and hands **13** in the display area.

Variation 15

FIG. **19** is a plan view of an electronic timepiece **200** according to variation 15.

The electronic timepiece **200** in this variation has a rectangular case in which an annular antenna **42**, annular ground plane **98**, and LCD panel **15** are housed. The LCD panel **15** displays time digitally. The antenna **42** and ground plane **98** are both substantially rectangular annular shapes disposed coaxially to the center point CA. While the shape of the ring differs from the antenna **40** shown in FIG. **6**, the antenna **42** similarly has a base (dielectric), parasitic element, driven element, and coupling part, and a specific potential is supplied to the driven element through the feed pin and coupling part. In addition, while the shape of the ring differs from the ground plane **90** shown in FIG. **5**, the ground plane **98** also includes a plurality of conductive pins and conductive springs, and the ground potential is supplied thereto through these conductive pins and conductive springs.

As described with the antenna **40** and ground plane **90** above, the distance on the z-axis between the antenna **42** and ground plane **98** is less than or equal to h, where h is the thickness on the z-axis of the base (dielectric) of the antenna **42**. The antenna **42** and ground plane **98** thus have the same center CA, and are disposed on the z-axis with a gap therebetween of h or less on the z-axis. The electronic timepiece with internal antenna according to the invention can thus display time digitally, and the annular shape of the dielectric and ground plane can also be a rectangle or other polygon, or an oval.

Variation 16

The antenna **40** (base **401**) and ground plane **90** do not need to be disposed coaxially. What is essential is that the opening **406** in the base **401** and the opening **90***c* in the ground plane **90** overlap each other at least in part when the electronic timepiece **100** is seen in plan view (that is, when the base **401** and ground plane **90** are seen in line with the center axis of the rings). In addition, the gap ⊗ d between the antenna **40** (base **401**) and the ground plane **90** must be less than or equal to the distance at which the ground plane **90** and driven element **403** can be made to resonate. This also applies to variation 15, for example.

Variation 17

The side of the case in the foregoing embodiments includes the case **80** and bezel **81**, but the side of the case can be manufactured as a single member by molding a plastic, ceramic, or other non-conductive material.

A charging method other than solar charging may also be used. For example, a charging coil can be used to charge the storage battery with power produced by electromagnetic induction from an external charger.

A lithium battery or other primary cell can also be used instead of a storage battery **27**.

Variation 18

The foregoing embodiments are described using GPS satellites, but the invention is not so limited and can be used with Global Navigation Satellite Systems (GNSS) such as Galileo (EU), GLONASS (Russia), Beidou (China), and IRNSS (India), as well as the Satellite Based Augmentation System (SBAS) or the Quasi-Zenith Satellite System (QZSS). An electronic timepiece with internal antenna according to the invention can thus receive radio signals from manmade satellites other than GPS satellites **20** to adjust the internal time. The electronic timepiece with internal antenna according to the invention is also not limited to radio signals from manmade satellites, and the invention can also be applied in an electronic timepiece that receives 900 MHz band signals for RF tags.

Variation 19

An electronic timepiece with internal antenna according to the invention is not limited to wristwatches, and could be a pocket watch or table clock, for example. The invention can also be used in electronic devices with an electronic timepiece function (such as cell phones and digital cameras).

Although the present invention has been described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims, unless they depart therefrom.

The entire disclosure of Japanese Patent Application No. 2012-209024, filed Sep. 24, 2012 is expressly incorporated by reference herein.

What is claimed is:

1. An electronic timepiece with internal antenna, comprising:

a time display unit that displays time;

an annular dielectric body that is housed in the case and has disposed thereto a conductive driven element to which a specific potential is supplied; and

a conductive ground plane with an annular shape that is supplied with ground potential;

wherein the dielectric body and the ground plane are disposed coaxially to the same center axis with the gap therebetween in the axial direction less than or equal to the thickness of the dielectric in the axial direction.

2. The electronic timepiece with internal antenna described in claim **1**, wherein:

the ground plane has a plurality of supply parts to which the ground potential is supplied.

3. The electronic timepiece with internal antenna described in claim **2**, wherein:

the plural supply parts are disposed at equal angles from the center of the ground plane ring.

4. The electronic timepiece with internal antenna described in claim **2**, wherein:

the driven element is an endless ring or a ring with a notch therein, and when the dielectric and ground plane are seen in plan view from the axial direction of the ring, the plural supply parts are disposed symmetrically to a line joining the center of the ground plane ring and the driven part.

5. The electronic timepiece with internal antenna described in claim **1**, wherein:

the driven element is a ring with a notch therein, and has one driven part to which the specific potential is fed;

a supply part to which the ground potential is supplied is disposed to one place on the ground plane; and

when the dielectric and ground plane are seen in plan view from the axial direction of the ring, the supply part is disposed to apart in a range from the midpoint between the ends of the driven element and the driven part.

6. The electronic timepiece with internal antenna described in claim **1**, further comprising:

a case that has a conductive case body that has a cylindrical shape and is supplied with the ground potential, wherein

an annular dielectric body is housed in the case;

the gap between the inside surface of the case body and the outside surface of the dielectric is less than or equal to the thickness of the dielectric; and

the overlap of the case body and the dielectric in the axial direction is greater than or equal to ⅕ the thickness of the dielectric.

7. The electronic timepiece with internal antenna described in claim **1**, further comprising:

a case that has a conductive case body with a cylindrical shape, and a conductive back cover connected to the case body; wherein

the ground potential is supplied to the case body and the back cover.

8. The electronic timepiece with internal antenna described in claim **1**, wherein:

a conductive parasitic element that is an endless ring or a ring with a notch therein is disposed to the dielectric with a gap to the driven element.

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